Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE

JOURNAL OF GEOLOGY

NOVEMBER-DECEMBER, 1910

A CENTRAL AFRICAN GLACIER OF TRIASSIC AGE[1]

SYDNEY H. BALL AND MILLARD K. SHALER
New York City, N.Y.

INTRODUCTION

From June, 1907, to June, 1909, the writers directed the prospecting work of the Société Internationale Forestière et Minière du Congo in the Belgian Congo, more familiarly known by its former name, the Congo Free State (Fig. 1). In the zone of the Maniema (Fig. 2), in the eastern part of the colony, evidences of glacial action of Jura-Triassic age were noted, which seem worthy of description.

The data of a scientific nature were collected during the two years passed in the Belgian Congo, incidental to an economic reconnaissance of the country, and is consequently of a fragmentary character. Difficulties of work in a partially explored tropical country also explain the lack of detail in this paper. Topography by R. B. Oliver is the base used, and field notes by A. E. Smith are drawn upon in the preparation of this paper.

LOCATION AND AREA

Belgian Congo lies in southwestern Central Africa to the west of the Continental Divide. It has a coast line of but twenty miles on the Atlantic, but widens rapidly eastward to points 5 degrees north and 14 degrees south of the equator. Its area is 908,000 square miles, or greater than that of all the United States east of the Mississippi River.

---

[1] Published by permission of the Société Internationale Forestière et Minière du Congo.

The zone of the Maniema is situated in the Upper Congo region, and includes that part of the Lualaba (Congo) Valley between latitudes 3 and 5 degrees south. The principal state post in the zone is Kasongo (Fig. 1).

TOPOGRAPHY AND DRAINAGE

From north to south, Africa is made up of three topographic elements: the Atlas Mountains, a highly accentuated region of closely folded rock; the Soudan and Sahara desert region, a more or less accidented plain in which the rocks are, in the main, flat-lying; and the central and southern tablelands with the Abyssinian plateau, consisting of intensely folded older, and horizontal younger rocks.

The Belgian Congo lies within the plateau region, and consists from west to east of: (1) a narrow coastal plain, which faces the Atlantic Ocean, rising to (2) an ancient mountain range, now eroded to an intensely dissected plateau, and frequently referred to as the Crystal Mountains (the higher domes reach an altitude of 2,300 feet; through the hard rocks of this plateau the mighty Congo rushes in a series of rapids, and low waterfalls, the non-navigable stretch between the Lower and Upper Congo rivers); (3) the great interior region, a basin whose slopes rise gently from Lake Leopold II (altitude 1,110 feet). The limits of the basin to the north (altitudes from 2,500 to 4,200 feet) and to the south (from 4,000 to 5,000 feet) are comparatively low, but to the east rise the Eastern Frontier Mountains, in height averaging about one mile above sea-level. Certain peaks like the volcanic Ruwenzori (altitude 16,800 feet) rise to altitudes exceeding 15,000. These mountains are in part due to folding, but largely to north-and-south faulting with which are genetically connected important volcanic phenomena.

The Congo River and its tributaries drain the Belgian Congo with the exception of a small area in the extreme northeastern part, the waters of which find their way into the Nile. The principal affluents of the Congo are the Kasai, Sankuru, and Ubangi. It is 4,640 kilometers in length, and the sixth longest river in the world.

GENERAL GEOLOGY (Fig. 1)

The coastal plain is underlain by marine sandstones which are inclined gently toward the ocean. The sandstones, which are covered by recent alluvium at the Congo mouth, are considered by geologists who are familiar with them to be of Tertiary and Cretaceous age.

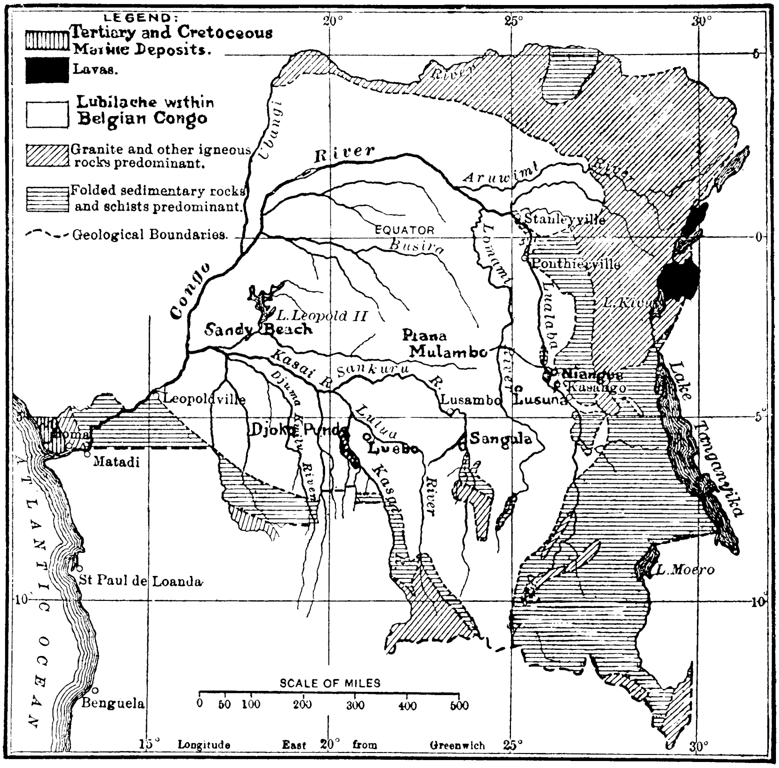

FIG. 1.—Showing approximate geological boundaries in the Belgian Congo

The so-called Crystal Mountains consist of older rocks, the age of which has not yet been satisfactorily determined. The older members of the series consist of mica schists and sericitic quartzites, interbedded with which are chlorite and epidote schists, representing either basic lavas contemporaneous with the sedimentary rocks, or very ancient intrusive bodies of igneous rocks.

Of later origin are intrusive masses of granite and gabbro, now mashed and recrystallized into gneisses. Large bodies of granite and smaller ones of diabase also occur.

To the east of these older rocks are limestones and calcareous schists, which near the ancient complex are closely folded, but are flat-lying farther east, half-way between Matadi and Leopoldville. These beds are considered by E. Dupont[1] to be of Devonian age. To the east they are unconformably overlain by red sandstones and shales, the Kundulungu (Permo-Carboniferous) of Professor Jules Cornet.[2]

The great interior region is covered by the Lubilache formation, a series of interbedded sandstones and shales, either flat-lying or dipping gently toward the center of the basin. The formation, the lower surface of which is undulating, thins rapidly on the upper slopes of the basin. As the rim of the basin is approached, isolated inliers of older folded and faulted rocks begin to appear where valleys cut through the sandstone-shale blanket, and encounter low domes on the old surface.

These older rocks are similar, in a general way, to those of the Crystal Mountains. They consist of very ancient mica schists, quartzites, and igneous schists and gneisses, which are cut by gabbros and granites. Younger than the granites are folded sandstones, quartzites, slates, shales, and limestones. Cornet is, without much question, correct in his belief that these two series of rocks are respectively of pre-Cambrian and Paleozoic age, although, unfortunately fossils have nowhere been found in them. In the Eastern Mountain area are also modern and Tertiary lavas.

The main structural features on the north and south rims of the Congo basin have an east-and-west trend, while the rocks of the Eastern Mountains strike north-and-south. The position of Lakes Tanganyika, Kivu, Albert Edward, and Albert and of the mountain ranges near by has been determined largely by faults, the trends of which are approximately parallel to the strike of the rocks.

---

[1] *Lettres sur le Congo* (1889), Paris.

[2] *Bulletin Société Géologique de Belgique,* XXI, 262.

LUBILACHE FORMATION

The Lubilache formation, in which the glacial features occur, was first described by Dupont[1] and named by Cornet[2] from the Lubilache (Sankuru) River, where it is typically developed. It is the essentially flat-lying sandstone-shale series which covers the central Congo basin, not rarely extends in tongues into the rim plateau and mountain regions, and at several points crosses beyond the Congo basin. In general this series is made up of sandstones and shales in alternating beds, which grade into one another both laterally and vertically.

As a rule massive bedding predominates in the sandstones as does a reddish color; grayish and white beds are, however, not uncommon.

In the lower Kasai region particularly, a quartzitic phase is often developed in the sandstones by the deposition of secondary silica by surface waters. In extreme instances this action results in a rock almost cherty in character, which is often cellular, the weathered surface being pitted. In the upper Kasai and Sankuru regions this quartzitic phase is rare, the sandstones being medium grained and having usually a saccharoidal texture. In the Lualaba (Upper Congo) area hard, fine-grained maroon sandstones cemented with a ferruginous pigment predominate. In all cases the sandstones are typically quartzose, although near the base of the formation at many places, feldspathic material is present.

The shales are usually fissile and vary in color from greenish gray to tan and drab.

In the vicinity of Nyangwe, on the Lualaba River (Upper Congo), shales, well exposed, are more or less bituminous, but grade laterally both up and down the river into more arenaceous beds. West of Kasongo, toward Lusunu, these beds are almost sandstones.

The basal beds of the formation are generally slightly conglomeratic. In the vicinity of the junction of the Lulua and Kasai rivers the ancient erosional surface upon which the flat-lying sandstones and shales were deposited undulated very gently. The down-cutting of the stream valleys has exposed, at numerous places, the summits of the greater elevations of this ancient surface. While the contact is poorly exposed, the basal beds are seen to be nowhere coarsely conglomeratic nor to contain many pebbles. The well-rounded pebbles consist of quartz, chert, and granite, all probably derived from the so-called pre-Cambrian series. They are usually confined to the twenty feet immediately above the contact, although in instances they occur considerably higher.

---

[1] Dupont, *op. cit.*

[2] Cornet, *op. cit.*, XXI, 211.

Between Luebo and Lusuna, where the base of the series is not seen, conglomeratic beds or lenses were noted interbedded with sandstone. In the Lualaba Valley within the zone of the Maniema a basal conglomerate, which will be described later, is frequently exposed in the valleys of the streams.

The vertical range between the base and top of the Lubilache is probably somewhat greater than 1,500 feet. At no one locality however, known to the writers, is this entire thickness exposed. In the upper Kasai region, between Luebo and Djoka Punda, monadnocks, principally of massive red sandstone of this series, rise 400 feet above the general plateau level, and 700 feet above the river at the places named, thus exposing approximately 700 feet of this formation.

In the Maniema the base of the series is considerably higher than in the Kasai region, the base averaging 2,000 feet in the former, and 1,550 feet in the latter region. As the beds were deposited in what appears to have been one and the same lake, this difference in elevation is due probably to north-and-south faults parallel to Tanganyika Lake. These successively have raised the country from west to east upward. Evidence of this is seen in the isolated outlier of sandstone in the Luiko Valley, later to be described (see p. 691).

Initial dips up to 5 or even 10 degrees were noted in the zone of the Maniema, particularly where the sandstone occupies ancient fjords extending up into the old mountains, and a slight initial dip occurs away from the mountain masses toward the center of the larger basins of deposition. For the most part, however, the formation is essentially flat-lying, and with few exceptions the dip can be measured only in feet per mile and not in degrees.

AGE OF THE LUBILACHE

Studt,[1] from general stratigraphic relations, considers the Lubilache in the Katanga to be the equivalent of the Stormberg member (Trias) of the Karoo. This correlation is confirmed by fossils collected by us. While these plant and animal remains are of a fragmentary character, they are nevertheless sufficient to place rather definitely the horizons from which they were collected. Dr. E. O. Ulrich, of the U.S. Geological Survey, kindly determined the fossils, and places the age of the series probably in Jura-Triassic time. Fossils were found by us, and described by Dr. Ulrich as follows: Shale from Niangwe 200 feet above base of Lubilache series: "Fragments of plants undeterminable."

Chert from Sandy Beach (on Congo, 130 miles above Leopoldville) perhaps 150 feet above base: "Probable broken sponge spicules and suggestions of branching sponges."

Limy shales ten miles below Stanleyville and 150 (?) feet above the base of series, Dr. Ulrich states:

> These are crowded with Ostracoda and with these fewer bivalved phyllopods and fragmentary dermal ossicles of ganoid fishes. So far as observed the Ostracoda belong to fresh and brackish water species of *Cypris* and *Candona* and perhaps other genera of Cypridae. Unfortunately the form in these Ostracoda is very similar in species, ranging from Pennsylvanian on to recent times. But the alliances of your specimens seem to be rather nearer Mesozoic species than to Tertiary. . . . .
>
> With the Ostracoda I find a single valve of a neat *Estheria*. The surface ornament appears minutely radiate under a hand lens but more closely examined is found to consist of sharp radially disposed bars crossing the flat spaces between the concentric ridges. This type of ornament is found in two recent species (*E. donaciformis* and *E. similis* Baird) and also in two Mesozoic species (*E. elliptica* Dunker and *E. subquadrata* Sowerby), but the Stanleyville species evidently differs in outline from all of these and doubtless represents a distinct, probably new, species. The fish remains are too fragmentary to be determined.

Mr. R. Kotska, prospector of the Lower Congo–Katanga Railroad, found a fossil crustacean at Sangula at the confluence of the Buschinmai and Sankuru rivers. This specimen has been turned over to us through the kindness of officers of that company. The prospector, a man with considerable geological knowledge, describes the rock as flat-lying, "grès tendre," the common Belgian name for the Lubilache formation. The matrix in which the fossil occurs is typical of the soft sandstone seen by the authors at Lusambo, 60 miles to the north of Sangula. There is then no doubt in the minds of the writers that this is from the Lubilache formation. Concerning this fossil Dr. Ulrich says:

---

[1] *Annales du Musée du Congo*, série II, "Katanga" (Bruxelles, 1908), 14.

> It is a bivalved crustacean, apparently of the genus *Estheria:* and so far as known to me the largest species of this genus yet found. The species seems distinct from all the described forms.
>
> Looking over the fossils again, my belief has grown to conviction that the bed from which these fossils were procured is Mesozoic and Jura-Triassic, rather than later.

While the fossils are by no means strongly indicative of the climatic conditions under which they lived, Dr. Ulrich states that if they indicate anything concerning the climate it would be that it was relatively moist and rather cool. The water was either fresh or brackish.

DEPOSITION OF THE LUBILACHE

The Lubilache formation was deposited in a Triassic lake of fresh or brackish water, which may have been connected with the ocean. On the railroad at kilometer 115, in the Lower Congo, residual bowlders of what one of us (S. H. B.) takes to be the Lubilache formation, occur on the west side of the present divide of the plateau, commonly called the Crystal Mountains. It is hence more than probable that this ancient lake was once connected with the ocean by one or more straits. From the present distribution of the Lubilache beds this lake was at least 900 miles in diameter, and was probably much larger. The bed of the lake was an undulating surface, and the body of water was surrounded by low land to the west, north, and south, but with at least hilly country to the east. These eastern hills in instances must have been 2,000 feet high. Between them ran valleys, some of which appear to have been deep and abrupt enough to have been worthy of the name of "fjords." While the Lubilache was being deposited it is more than likely that the central part of the lake basin around the present Lake Leopold II was a sinking area. At no time does the lake appear to have been deep, except in certain valleys extending into the mountains. Cross-bedding is common, as are rapid changes from sandstone to shale, probably best to be interpreted by current scouring. The nature of the sediments indicate deep disintegration of the rocks near the shore, while from the fossils Dr. Ulrich is inclined to believe the water to have been at least cool.

LUBILACHE IN THE ZONE OF THE MANIEMA

In the Maniema zone in the Lualaba Valley and in the valleys of its tributaries, west of the Eastern Frontier Mountains, the Lubilache covers a large area, as shown in Fig. 2. Within the zone isolated hills and mountain groups of older granites, gneisses, schists, and folded sedimentary rocks rise above the dissected plain of the flat-lying series. These older rocks probably stood as islands in the lake in which the Lubilache was deposited.

The general character of the beds of this series has been described, but a more detailed description of the basal beds will be given, as it is at this horizon that evidences of glacial action were noted.

LUBILACHE BASAL CONGLOMERATE IN THE MANIEMA

The basal beds are best exposed along the Lualaba River, and the lower Lulindi, and here they have an entirely different character from elsewhere in the Maniema and other districts, as known to the writers. Indeed very coarse conglomerates at the base of these flat-lying sandstones and shales are confined to the immediate valleys of these streams. Elsewhere where the conglomeratic phase occurs the pebbles are rarely over an inch in diameter and sparsely distributed. This is true even where conglomeratic beds occur around the hills of granites, schists, and other older rocks.

In the immediate valley of the Lualaba and lower Lulindi rivers, between 3° 30′ and 5° south of the equator (our work did not extend south of the 5th parallel) the basal 5 to 20 feet of the Lubilache is an exceedingly coarse conglomerate. This conglomerate is morainal material, deposited by a tongue of a glacier which followed down the Lualaba Valley probably prior to its becoming a gulf of the great body of water in which the Lubilache was deposited. The morainal matter appears to have been but slightly reworked by the waters of the lake.

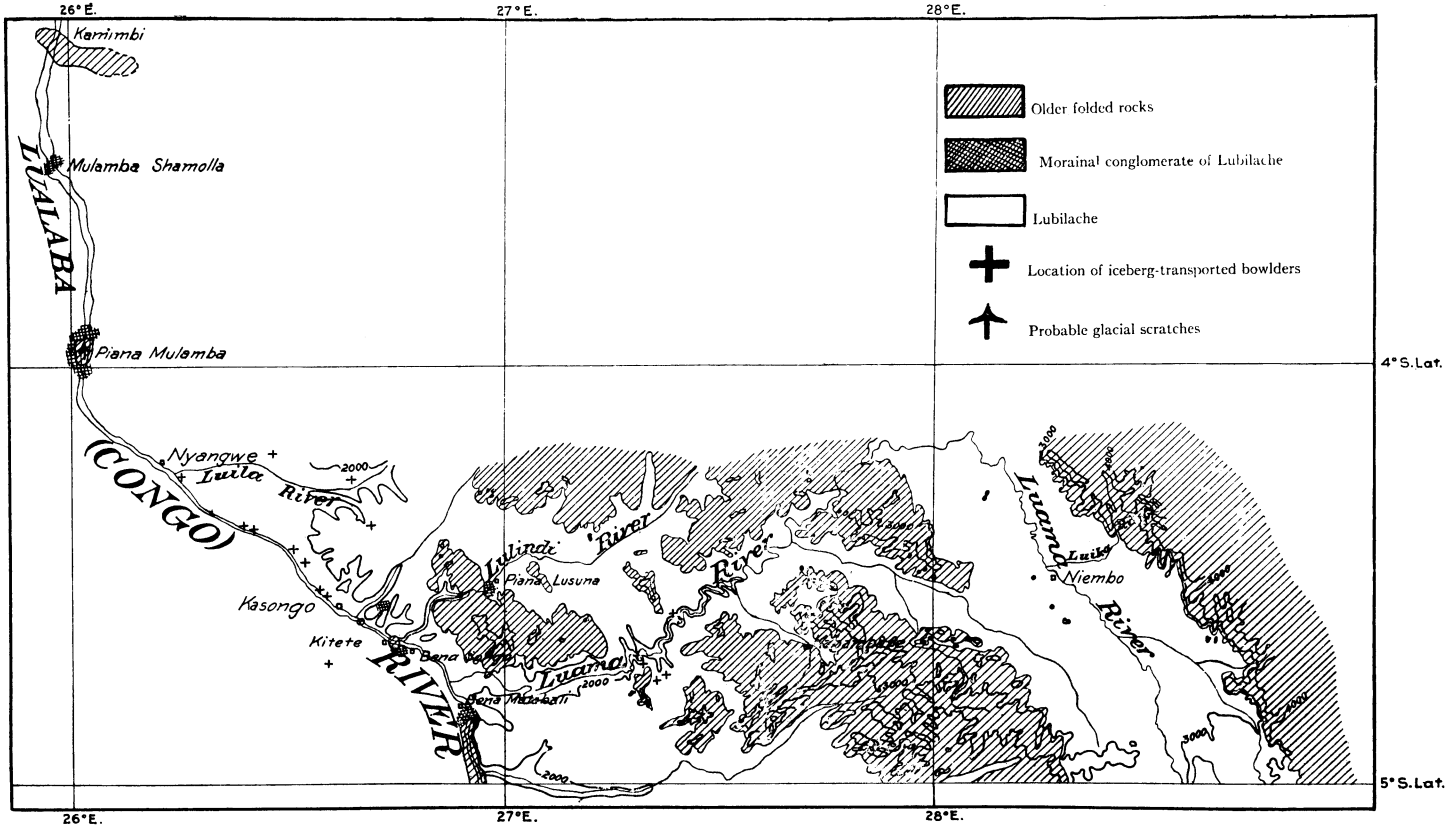

FIG. 2.—Map of Maniema. Scale $\frac{1}{2,000,000}$ (after indicated reduction); contour interval 1,000 feet

Before the formation of the great interior lake or sea in which the Lubilache was deposited the Congo Valley was probably a most important depression and after the subsidence the upper portion of the valley formed a wide but rather shallow gulf with arms reaching in instances into valleys of the eastern mountain range itself. A small isolated remnant of flat-lying sandstone having the general lithologic character of the upper beds of the Lubilache, as exposed in the Maniema, was found in the Eastern Mountains in the Luiko Valley. This outlier is only a few feet in thickness, and lies in a small tributary valley on an uneven, eroded surface of gneiss. Its elevation above sea-level is about 4,800 feet, or nearly 2,000 feet above the highest horizontal rocks known in the region, the sandstone forming Niembo Mountain near Niembo (Fig. 2). This great difference in elevation is due to profound north-and-south faulting along the western front of the Eastern Mountains, but the presence of horizontal sandstone beds in a small valley at a considerable distance from the main area of flat-lying rocks is unquestionably due to its having been deposited in an antecedent valley, the sides of which protected it from complete removal by erosion. This outlier, and the residuals of apparent Lubilache in the Bas-Congo, show that this formation once had much wider distribution than at present.

A type of the Lualaba River basal beds is exposed along the Lulindi River, just downstream from the crossing of the telegraph line, and near the village of Piana Lusuna. This is fifteen miles from the present Lualaba River, and 275 feet above it at Kasongo. The older rocks unconformably underlying the Lubilache are not exposed here, but typical basal beds occur for 200 feet laterally along the river. The matrix of the conglomerate is a yellow, incoherent, fine-grained, slightly argillaceous sandstone. The exposure is apparently flat-lying. Small bodies are wholly without bedding, others are thinly laminated, while still others have a swirly bedding, the thin laminae curving in concentric bands. Cross-bedding is not rare. The distribution of the bowlders and pebbles is patchy; areas 2 to 40 feet across being without pebbles, while between are heavily conglomeratic areas. In the same conglomeratic mass coarse sand and bowlders 4 feet across occur. The smaller pebbles are usually well rounded; the larger are angular or only roughly rounded; the medium-sized bowlders, those from 2 to 6 inches in length, are three or four cornered and often striated.

The striations are especially well seen on dense, close-textured rocks, quartzite for example (Plate I). These can scarcely be other than glacial striations. While through desert erosion somewhat similar scratches are produced, they are too abundant here on a single bowlder, and the familiar tiny crescentric fractures (nicks), caused by the striking of one bowlder by another in descending the cloud-burst swept valleys of arid regions, are absent.

With but slight variations this description would answer for the exposures on the Lualaba River at the Kitete Rapids where the Lubilache is in contact with quartzite; at Bena Songo and Bena Matabali Rapids; at Piana Mulambo where the Lubilache lies on slaty quartzite more or less folded; and at Mulambo Shamola. The principal and most constant differences lie in a slight variation in the character of the matrix, which varies in color from whitish yellow to greenish gray or dark gray, and in the degree of consolidation. The matrix, which is usually incoherent, is well consolidated at Piana Mulambo and Mulambo Shamola. At Bena Songo the irregular distribution of the bowlders is well seen, many occurring for 100 feet laterally, and none in the next 100 feet.

Where the underlying older rocks are exposed the bowlders derived from them are more abundant and more angular than the bowlders of other varieties. The bowlders and pebbles consist of quartzite, of granites and gneisses, of limestones, etc. It is worthy of note that at the most northerly of these outcrops of basal conglomerates at Mulambo Shamola, the larger pebbles are but six inches in diameter. There are at all other localities great bowlders two to three feet in diameter, of rocks not known to occur in the immediate vicinity, that is, large bowlders which have been transported considerable distances. Typical examples of the contact of these basal beds with the older rocks are seen in Fig. 3, A and B representing respectively the contact with quartzite at the head of the Kitete Rapids, and the contact with slaty quartzite at Piana Mulambo.

PROBABLE GLACIAL SCRATCHES

Piana Mulambo is situated on the Lualaba River about fifty miles northwest of Kasongo (Fig. 2). One-quarter mile east of the house of the transport agent of the Grand Lakes Railroad at this village is a swift rapid in the river. On the west bank of the river, at the lower end of the rapids, highly inclined slaty quartzite beds are at the same elevation as the base of the Lubilache at the house mentioned. Fig. 3B represents the contact one mile south of the house. The slaty quartzites, owing to the differences in resistance to erosion of their beds, usually weather as sharp-crested ridges and saddles, but here and there are flat surfaces. On the upper surfaces and never on the sides of these flat exposures of the older rocks are peculiar gouges and scratches (see Fig. 4).

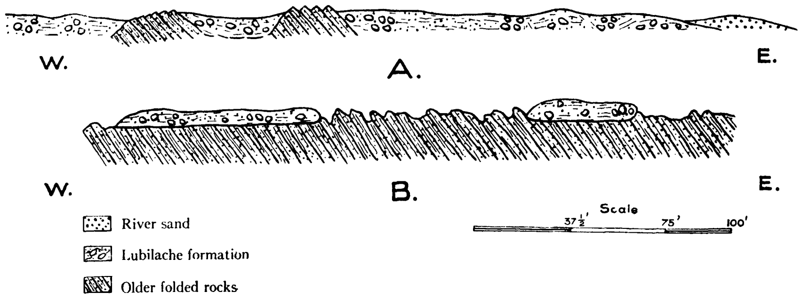

FIG. 3.—Contacts of Lubilache and older rocks on Lualaba River. A, Kitete Rapids; B, Piana Mulambo Rapids.

Coursing a little east of north and west of south these gouges and scratches have a rude parallelism. Some are cylindrical depressions from one to five feet long, and from one-half to three inches wide and deep. The ends are as a rule cigar-shaped and the surfaces of the grooves are striated with fine scratches from $\frac{1}{16}$ to $\frac{1}{4}$ inch apart. At the southern end is frequently a bowl-like depression, more deeply cut than the rest of the gouge. Local smoothings of the rocks occur finely striated with parallel scratches and in direction similar to the gouges described. At one place are three crescent-shaped gouges which course from east to west, with the concavity to the south. These, which resemble "crescentric gouges," are four inches in length, the central one being deepest and broadest (see Fig. 4).

These gouges occur level with the contact elsewhere, and do not resemble any river-worn scratches with which we are familiar. The grooves, crescentric gouges, and the finely striated planed surface appear to be of glacial origin, and indicate that the glacier once extended to at least this point, or to 4° south latitude. The glacier, from this evidence, advanced from south to north.

ERRATIC BOWLDERS

In the immediate Lualaba and Luama valleys in the Maniema, and for several miles on either side between Nyangwe and the 5th parallel south, the shale of the Lubilache has sparsely and irregularly scattered through its mass, pebbles and bowlders with a maximum diameter of five feet. These bowlders are not known to occur within the large areas of the Lubilache away from these rivers. They are usually well rounded, and consist of granites, quartzites, diorites, and other older rocks. There is in no case any change in the fineness or character of the well-laminated shale immediately surrounding these isolated bowlders.

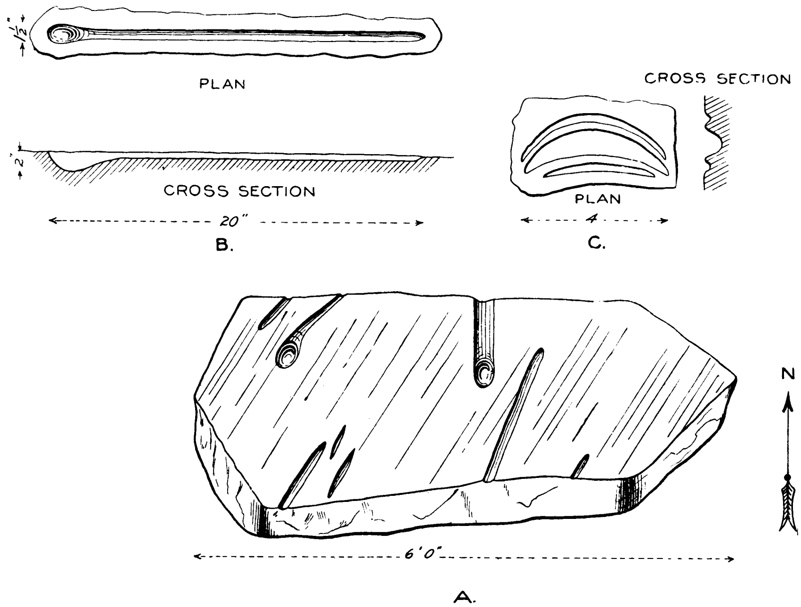

FIG. 4.—Probable glacial grooves and scratches on Paleozoic slaty quartzites, Piana Mulambo Waterfall, Lualaba River.

The laminae of the shale are concentric with the form of the bowlders, being slightly arched over, and greatly bowed under them, as if they had been dropped from considerable heights into a plastic mass.

Within the limits defined these bowlders occur at numerous localities, as shown in Fig. 2, at stratigraphic positions from 0–200 feet above the base of the formation. Two exceptions should be noted: At Bena Tomba, latitude 4° 30′ S., on the bank of the Lufubu River, and at Tubila on the Lualaba, latitude 1° 30′ S., bowlders of older rocks lie upon the surface. The underlying rock is the Lubilache shale. The source of these bowlders is not known; they may have weathered from the shale, or they may have been carried to the points named by the natives, by whom such hard rocks are used in grinding foodstuffs.

The largest bowlder noted is of granite and was found by Smith, about one mile north of the Luila River. This bowlder measured $5 \times 3 \times 3\frac{1}{2}$ feet. Numerous other large bowlders were noted in the shale northeast of Kasongo.

From the fineness of the inclosing shale, the size of these bowlders, and their great distance in many cases from their source, it is evident that they were dropped from some object floating on the surface of the body of water in which the Lubilache was deposited. They could have been transported in but one of two ways: (1) by being imbedded in the roots of floating trees, or (2) by being carried by icebergs.

That bowlders of such enormous weight could be transported in the roots of floating trees is improbable. Furthermore, the shales of the Lubilache are practically barren of vegetable remains, particularly fossil tree trunks; absolutely none of the latter having been noted. The bowlders are numerous along the Lualaba and are known nowhere else in the formation. It is scarcely conceivable that the shores of this portion of the basin of deposition were alone bordered by trees capable, when swept into the lake, of transporting bowlders of several tons weight in their roots. Moreover, fragments imbedded in tree roots are usually not only angular or subangular, but also small and of weathered rock; while in all cases the erratic bowlders of the Lubilache shale are rounded or subangular, and are frequently large and fresh. Further, at several places the bowlders are in excess of what can be considered the load of one tree. In shales elsewhere in the world which are known to have been deposited in lakes or seas with tree-lined shores, similar bowlders occur in but few instances.

We believe, then, that these bowlders were transported by icebergs, derived from glaciers, and which melted where perhaps arrested in their courses by cross-currents.

Nyangwe was apparently the northern limit to which these icebergs reached, although below Nyangwe the immediate Lualaba (Congo) Valley only was examined. From Nyangwe to 5° S., however, in almost every mile of Lubilache exposures traversed, these erratics were noted. As the morainal conglomerate extends south of Nyangwe, we have perhaps evidence here of the southward retreat of the glacier in early Lubilache times.

RÉSUMÉ OF EVIDENCES OF GLACIATION

It is concluded from the evidence given above that during Triassic time at the beginning of the deposition of the Lubilache series, a glacier, or glaciers pushed in a tongue down the present valley of the Lualaba River; from the fact that large bowlders, probably dropped by icebergs, are found at least 200 feet above the base of the formation, it is believed that long after the glacier had retreated toward the south, glaciers still existed to the southeast. This glacial epoch, therefore, must have been of a considerable duration.

The glacial features presented by the Lubilache formation contiguous to the Lualaba Valley in the Maniema are:

1. Striations, having the characteristics of glacial striations, on pebbles in the basal conglomerate of this series, indicating morainal origin.

2. The tongue-like form of the basal Lubilache beds in the Lualaba Valley, and the character of this conglomerate, including the size of the bowlders, the lack of assortment, the patchy arrangement of the material, and the preponderance of bowlders of local origin.

3. Erratic bowlders, presumably dropped by icebergs, occurring

in shales of this series as far north as the latitude of Nyangwe which have been seen only near the Lualaba Valley.

4. Probable glacial scratches, crescentric gouges, and smoothings on the surfaces of older rocks upon which the Lubilache was laid down.

The presence of glaciers being, in the writers' mind, proved by the above evidence, it remains to determine, in so far as possible, the character of the glaciers, the climatic condition under which they existed, their extent, and their relation to the Permo-Carboniferous glaciers of South Africa.

AFRICAN EQUATORIAL GLACIERS OF THE PRESENT DAY

Chamberlin and Salisbury[1] state that in equatorial regions the snow line has an altitude of from 15,000 to 18,000 feet.

Small mountain glaciers are known on three of the highest peaks of equatorial Africa. Hans Meyer[2] found on Kilima Njaro (3° S.) small glaciers with lower limits at an elevation of 4,300 meters (14,100 feet). On Ruwenzori (1° N.) E. S. Moore[3] found several glaciers with the snow line at 13,500 feet above sea-level.

Scott Elliot[4] gives the snow line on this same mountain as 15,500 feet. J. W. Gregory[5] found glaciers on Mount Kenia situated on the equator. The lower ends of these glaciers are 15,500 feet above sea-level; the snow line being at 16,000 feet. Scott Elliot[6] believed that formerly glacial action extended to 5,200 feet on Ruwenzori. Gregory[7] found evidences of old glaciers on Kenia at about 10,000 feet, and Meyer[8] states that on Kilima Njaro the glaciers once pushed down to lower levels. Among certain geographers the conclusions concerning these Pleistocene glaciers are doubted.

---

[1] *Geology*, I, 246.

[2] Hans Meyer, *Verhandlungen der Gesells. für Erdkunde der Berlin*, XXVI (1899), 100.

[3] *The Tanganyika Problem* (London, 1903), 102.

[4] *A Naturalist in Mid-Africa* (London, 1896), 175.

[5] *Geographical Journal*, IV (1894), 419–20.

[6] Elliot, *op. cit.*, 172.

[7] Gregory, *op. cit.*

[8] Meyer, *op. cit.*

PROBABLE ELEVATION OF LUBILACHE BEDS WHEN DEPOSITED

The base of the Lubilache formation at Luebo at the present day is 1,475 feet above sea-level. In the Maniema, due to uplift by north-and-south faults, the basal beds lie at a higher elevation (1,800 to 2,400 feet), while near Lake Leopold II (1,110 feet), through subsidence of the beds, the country rock is well up in the Lubilache. It is believed that the elevation of the basal beds at Luebo is considerably above that of the lake bottom in which the Lubilache was deposited. It has before been mentioned that residuals of what appears to be the Lubilache formation were found in the Lower Congo, indicating that the lake was probably once connected with the ocean. Other evidence also points to the uplift in later geological times of the Crystal Mountain region to an elevation of 3,400 feet above sea-level. On the coast there is an indistinct zonal distribution of the Tertiary and Cretaceous sedimentary rocks, the later being farther inland. The Crystal Mountains themselves are a peneplain, which has been uplifted presumably by faults coursing west of north and east of south. The Congo River valley through the Crystal Mountains is young topographically and indicates recent uplift, and yet the amount of erosion which the peneplain has suffered would lead one to place its development back at least as far as the Cretaceous. At some time then during or prior to the Cretaceous we may believe the Congo basin to have been practically at sea-level. All evidence at hand indicates that the Lubilache formation was laid down in a lake of which the bed was at, or but slightly above, sea-level.

Only to the east did high hills arise, and from the lack of bowlders in the Lubilache immediately surrounding these hills, it is doubted if they reached a maximum elevation of over 2,000 feet above the lake surface.

SIZE OF GLACIER

The known extent of the morainal basal conglomerate in the Maniema (at least 100 miles from north to south) is many times greater than any tropical glacier now existing. Further, if the bottom of the Lubilache lake was at as low an elevation as we believe it to have been, we must rank this glacier in size with glaciers of the Malaspina type, if not with continental glaciers.

CLIMATIC CONDITIONS

Dr. Ulrich is inclined to believe the fossils indicate cool waters, and the writers think that, while the glacial conditions were induced partially by the altitude of the region in which they formed, they were largely due to climatic changes. At present, due to faulting comparatively recent in the geological sense, some of the mountains between the Lualaba River and Lake Tanganyika are 9,000 feet high. It is doubtful whether as great elevations existed in the Maniema during Lubilache time.

LOCATION OF THE GLACIER

The position of the glacier can be located only in a most general way. It appears to have been south of the Maniema.

The disappearance of the glacial conglomerate and the iceberg-borne bowlders to the north indicates that the source of the glacial material was to the south. Of similar import is the fact that the supposed glacial striations have a north-and-south orientation, while the concavity of the crescentric gouges indicates a movement from south to north.

Toward the south the work of the writers extended only to the fifth parallel. Professor Cornet's work in 1901–3 was within the Katanga, between latitudes 8° and 12° S. and longitudes 28° to 23° 31′ E. Between Professor Cornet's work and the fifth parallel, lies a considerable area in which the geology has not been studied even in reconnaissance.

To the southeast of Kabambare are mountains where these glaciers probably existed in Lubilache time, reaching today elevations of 9,000 feet; in Lubilache time they were presumably not so high. The Luama River heads in these mountains, and as the erratic bowlders are found along its course, as well as that of the Lualaba, it is possible that the valley then existed and that the glacier pushed north and then west and northwest from these mountains to the Lualaba.

Another possible but not probable location of the glaciers is found in the mountains to the northeast of Kasongo, the glaciers descending the Lulindi River to the Lualaba, thence being deflected northward along its valley. Northwest of Neimbo (Fig. 2) and in other places in the Kabambare region at the contacts between beds of Lubilache and the older rocks, conglomerates are notably absent, which argues against a source of the glacier in the general region of Kabambare.

RELATION TO PERMO-CARBONIFEROUS GLACIATION IN SOUTH AFRICA

It has long been recognized that the Dwyka conglomerate at the base of the Karoo formation in South Africa is a glacial moraine, more or less reworked by water. These continental glaciers of Permo-Carboniferous age lay to the north of Cape Colony,[1] and from this center pushed southward.

The most northerly occurrence[2] of this conglomerate is in latitude 25° 40′ S.

The Stormberg beds, with which former Congolese geologists have correlated the Lubilache, is a much younger formation of Rhaetic age (close of Triassic); while, as Cornet[3] believes, the earlier Karoo members are probably represented by red sandstones named by him the "Kundulungu" formation. The fossil evidence here presented strengthens greatly this correlation.

When the Lubilache lake formed, a tongue of morainal material probably covered the Lualaba Valley. The bowlders, however, composing it are believed to be too fresh for it to have been the deposit of a Permo-Carboniferous glacier. Were such the case, weathering throughout Triassic time would almost certainly have destroyed the bowlders. Moreover, well up in the Lubilache formation iceberg-transported bowlders occur, indicating the presence of glaciers at that time somewhere to the south.

The source of the glaciers at the two periods appears to have been in the same general region, and it is possible that, in some area in northern Rhodesia or southern Belgian Congo, glaciers existed for the greater part of Permian and Triassic time.

[1] A. W. Rogers, *The Geology of Cape Colony* (London, 1905), 413.

[2] See map of Transvaal, by T. H. Hatch and G. S. Corstorphine, *The Geology of S. Africa*, London, 1905.

[3] Cornet, *op. cit.*, 413.

RÉSUMÉ

The geology of Central Africa is as yet too little known to discuss the possible bearing of this ancient glacier within the tropics upon the broad problems of general and glacial geology. It suffices to state that there appears to be reason to believe that in Triassic times, when tropical life flourished in polar regions, a temperate or coolish climate existed to the west of Lake Tanganyika in Central Africa 4° 30′ from the equator.

Knowlton[1] in describing the Triassic flora states that it indicates that there were "no or but slight seasonal changes due to alterations of hot and cold or wet and dry seasons." It was "on the whole a moist, warm, probably at least subtropical climate."[2] He mentions that Triassic floras have been found on the east coast of Greenland, and in Spitzbergen.

July 9, 1910

EXPLANATION OF PLATE

Plate I.—Glacial-scratched bowlders; basal conglomerate. Lubilache formation, Lulindi River, near Piana Lusuna.

---

[1] *Journal of Geology*, XVIII, 107.

[2] *Ibid.*, 106.

Plate I